ORIGINAL ARTICLE

Effect of Foliar Fungicide, Tillage and Variety on Maize Gray Leaf Spot (*Cercospora zeae-maydis*) at Bako, Ethiopia

Meseret Negash

OARI, Bako, P.O.Box 03

E-mail: meseret.negash@yahoo.com

ABSTRACT

Maize gray leaf spot (*Cercospora zeae-maydis)* is one of the major constraints of maize (*Zea mays)* production in Ethiopia, especially where warm humid environmental condition prevails. Thus, this study was conducted to determine effects of foliar fungicide, tillage and maize variety on gray leaf spot disease development at Bako, Ethiopia. The experiment was laid out in factorial experiment in randomized complete block design in three replications. The treatments were three maize varieties, four tillage practices and two levels of mancozeb 80% WP. Significant variation was observed due to tillage x variety x fungicide interaction on severity, yield and yield components. BH-660 with conventional tillage and fungicide treatment gave the highest yield, while Phb-3255 with no-tillage and without application of fungicide gave the lowest yield. Similarly, lowest AUDPC and disease severity were recorded on BH-660 with conventional tillage and one time tillage practices with application of fungicide. The disease resulted in grain yield loss of up to 4.7, 37.1 and 46.9% on BH-660, BH-540 and Phb-3255, respectively. The average grain yield difference between sprayed and unsprayed plots of the same type of tillage practice exceeded the break-even yield in all tillage practices. Minimum or no-tillage was confirmed to contribute to more disease and greater yield loss irrespective of the variety used. Thus, use of one time tillage x BH-660 without fungicide spray, 2 times tillage x BH-540 with fungicide spray and 2 times tillage x Phb-3255 with fungicide spray are recommended for the management of gray leaf.

Key words: disease severity, grey leaf spot, hybrid maize, yield loss

INTRODUCTION

Maize (*Zeal mays* L.) is one of the popular crops grown in the world, ranking second to wheat and followed by rice (Vasal, 2000). It occupies an important position in the world economy as food, feed, and industrial grain crop and is among the leading cereal crops selected to achieve food self-sufficiency in Ethiopia (Benti *et al*., 1993). It is widely grown in most parts of the country and its production covers about 17% (nearly 2.05 million hectares) of land under cereal cultivation (CSA, 2011). Although improved cultivars have been largely included in the national extension package, the national average yield of maize is only 29.54 ton/ha (CSA 2011), which is far below the world average of 44 ton/ha (Dowswell *et al.,* 2009). The low yield is attributed to a combination of several constraints among which diseases play a major role. Foliar diseases particularly gray leaf spot (GLS) caused by *Cercospora zeae-maydis* is generally among the important constraints in tropical maize production (Renfro and Ullstrup, 1996).

Increased incidence of GLS in Africa has been associated with cultural practices such as reduced tillage, continuous cultivation of maize, and use of susceptible maize cultivars (Geyers *et al*., 1994). Conservation tillage leaves infested residue from previous crop on the soil surface that increases initial inoculum of the disease. While the beneficial effects of stubble tillage on soil and water conservation are widely recognized and the benefits are frequently offset by the increased crop damage due to fungal pathogens that survived in the previous season's residue (Anderson, 1995). In South Africa, stubble-related diseases have become major obstacles to the promotion of conservational tillage (Anderson, 1995).

GLS is particularly important in Africa because maize is the main staple food crop for millions of people in the region. It has the potential to endanger food security in many countries (Ward *et al.,* 1999). Documented yield losses of maize attributed to GLS vary from 11 to 69% (Ward *et al*., 1999b), with estimated losses as high as 100% when severe epidemics contributed to loss of photosynthetic area, increased stalk lodging, and premature plant death. The yield losses caused by the disease were estimated to reach 50% for moderately resistant and 65% for susceptible hybrid maize in South Africa (Ward *et al.,* 1999). Ward *et al.,* (1999) reported that, in South Africa, no commercial cultivars have been found to be resistant to GLS, but have identified high yielding hybrids that are less susceptible to the disease. Ward *et al*. (1994) in South Africa has shown that fungicides provide effective control of GLS of maize grown under stubble tillage.

GLS was first reported in Ethiopia in 1997 in the border of west Wollega and Ilubabor zones of western Ethiopia (Dagne *et al*., 2001). The survey report of Dagne *et al*. (2001) showed increased prevalence of GLS in the major maize producing regions of Western, Southern and Northwestern parts of Ethiopia. According to the report, GLS has become the principal maize disease since 1998 in Ethiopia. In Ethiopia, Dagne *et al*. (2004) reported that yield losses due to GLS on resistant, moderately resistant, and susceptible varieties were between 0 to14.9%, 13.7 to 18.3% and 20.8 to 36.9%, respectively from 2003-2004 cropping seasons in Bako and its surrounding areas.
Recently, even though it is not quantified, a number of farmers in maize belt area of Western Ethiopia have been familiarized with conservational tillage practice recommended by Farm Africa 2000 and intensified by Bureau of Agriculture. Though conservational tillage is an important practice, its large-scale application has been hindered by GLS associated with maize production. Furthermore, no information is available on the extent of GLS in association with different tillage practices. In view of the seriousness and potential destructiveness of GLS, different control options have been generated. However, no work has been done on the integration of options for managing this disease in maize in Ethiopia. Thus, this study was conducted to determine effects of foliar fungicide, tillage and maize variety on gray leaf spot disease development and yield and yield components.

MATERIALS AND METHODS

Experimental materials and procedures

The experiment was conducted at Bako Agricultural Research Center (BARC), Ethiopia, from June 2008 to December 2010. Twenty-four treatment combinations consisting of 4 levels of tillage, 3 levels of varieties and 2 levels of fungicide applications were used. The tillage levels were 0, 1, 2 and 3x (conventional) tillage using oxen drawn traditional maresha. In 0 tillage the soil was disturbed only for seed and fertilizer placement using hoe. The varieties used were BH-660 (resistant), BH-540 (moderately resistant) and PHB-3253 (susceptible). Fungicide (mancozeb 80% WP) was sprayed or unsprayed based on the treatment combinations.

Experimental design and treatment application

Treatments were arranged in factorial experiment using randomized complete block design (RCBD) with three replications. Each plot consisted of six rows of 4.5 m long spaced at 75 cm apart. The distance between hills was 30 cm. At planting two seeds were placed per hill which were later thinned to one after ensuring good establishment that gave a final plant density of approximately 44,000 plants/ha. Phosphorous (P_2O_5) was applied at planting time at the rate of 165 kg/ha, while 100 kg of nitrogen/ha (Urea) was applied in split, half at planting and the remaining half 37 days after emergence (at knee height). The non-selective herbicide (gramaxone) was used to control weeds in the no-tillage treatment. It was applied at the rate of 3 l/ha by a knap sack sprayer of 15 litres capacity four days before planting. Cultural weed control (including hoeing) practices and slashing were performed for all plots as deemed necessary.

Inoculation

Dry maize stover infested with *C.Zeae-maydis* was collected in 2007 and 2009 from maize field of 2007/8 and 2008/9 cropping season. This was chopped into small pieces to make it suitable for mulching the plots. One day before cultivation the chopped stover was evenly distributed on the experimental plots and incorporated into the soil with 1, 2 and 3x (conventional tillage) tillage at a density of about 30%, while the zero tillage plots were left unplowed.

Fungicide application

Mancozeb (80% WP) was applied at the rate of 175 g.a.i in 200 l/ha water, using knapsack sprayer of 15 litres capacity. Control plots were sprayed with water in the same manner with that of fungicide sprayed plots to prevent the differences among plots because of moisture. Fungicide was sprayed 0 to 4 times at 10 days interval starting from onset of the disease. The time and frequency of application of the fungicide varied according to the length of the period between the initiation of infection and crop physiological maturity.

Disease assessment

Disease incidence was recorded as percentage of plants showing GLS symptom. Disease severity was recorded six times at seven day interval by visual estimation of the amount of tissue damaged by the diseases. The disease severity estimates were rated using 1-9 disease scale (subrahmanyam *et al.*, 1995). Disease severity scores were then converted into percentage severity index (PSI) for the analysis using the formula stated below (Wheeler, 1969).

$$PSI = \frac{SNR \times 100}{No.PS \times MSS}$$

Where SNR = Sum of numerical rating, No.PS = number of plants scored and MSS = maximum score on scale. AUDPC of GLS severity was calculated for each treatment from all disease severity scores using the formula suggested by Shaner and Finney (1977) as follows:

$$AUDPC = \sum_{i=1}^{n-1} 0.5(x_{i+1} + x_i)(t_{i+1} - t_i)$$

Where, x_i is the cumulative disease severity expressed as a proportion at the i^{th} observation, x_{i+1} is cumulative disease severity at i^{th} plus one observation t_i is the time (days after sowing) at the i^{th} observation, t_{i+1} is the time at the ith pulse one observation and n is total number of observations. AUDPC values were used in analysis of variance to compare amount of disease among treatments.

Yield loss

Grain yield and 1000 kernel weight losses were calculated as the difference between mean yield of protected plots and unprotected plots of the respective tillage and variety. Losses were calculated separately for each of the treatments with different levels of disease using the formula:

$$YL(\%) = \frac{(Y_1 - Y_2)}{Y_1} \times 100$$

Where YL is yield loss, Y1 is yield of protected plots (plot with maximum protection) and Y2 is yield of unprotected plots.

Data analysis

Data on gray leaf spot incidence and severity from each assessment date, yield and yield components, AUDPC and all agronomic data were subjected to analysis of variance using SAS and MSTATC-C computer soft ware described by Gomez and Gomez (1984). Mean separation was based on the LSD at the 5% probability level.

RESULTS AND DISCUSSIONS

Disease progress

Regardless of the treatment GLS infected all varieties used. The disease onset was 54DAS on BH540 and Phb-3253 and 61DAS on BH-660. When maize was planted to no-tillage treatments where the field was infested with maize residues harboring *C zeae-maydis* that remained on the soil surface, the progress of GLS was faster. It reached more damaging levels than in maize planted in to conventionally tilled field. This was because infested residue greatly reduced due to inversion of the residue to the soil (Figure 1-4). The result of this experiment confirmed the observations of de Nazareno *et al*. (1993) who reported that epidemiologically, infested crop residue is the most important source of C. *zeae-maydis* inoculum. This was because in no-tillage practice the infested crop residue was not incorporated in to the soil and served as a source of abundant inoculum.

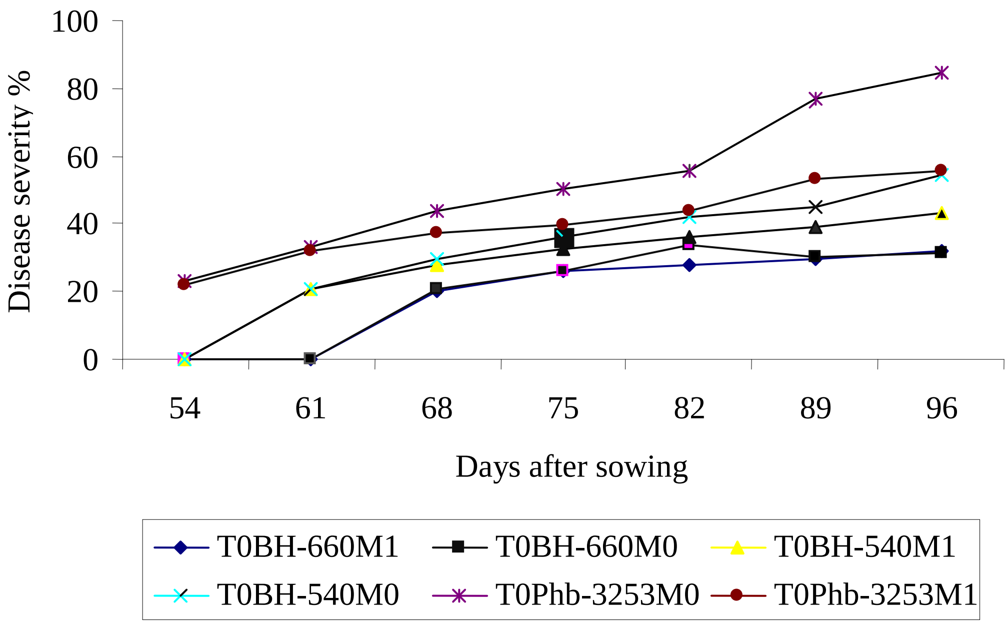

Figure 1. Disease progress curves of gray leaf spot under no-tillage practice and fungicide treatment on three maize hybrid varieties at Bako from 2008 to 2010 cropping seasons T0 = no-tillage, M0 = mancozeb 80% WP unsprayed, M1 = mancozeb 80% WP sprayed, BH-660= resistant, BH-540 = moderately resistant and PHB-3253= susceptible maize varieties..

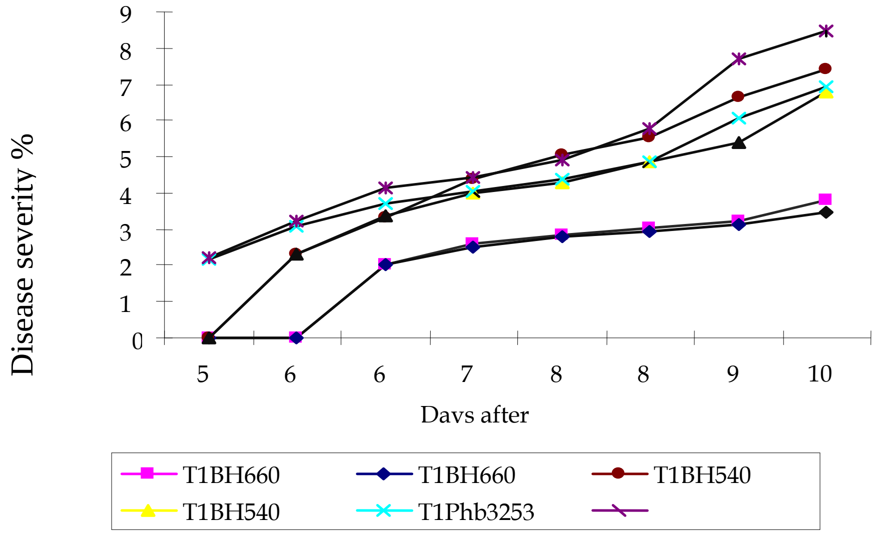

Figure 2. Disease progress curve of gray leaf spot under one time tillage and fungicide treatment on three maize hybrid varieties at Bako from 2008 to2010cropping seasons. T1 =1x tillage, M0 = mancozeb 80% WP unsprayed and M1 = mancozeb 80% WP sprayed, BH-660= resistant, BH-540 = moderately resistant and PHB-3253= susceptible maize varieties.

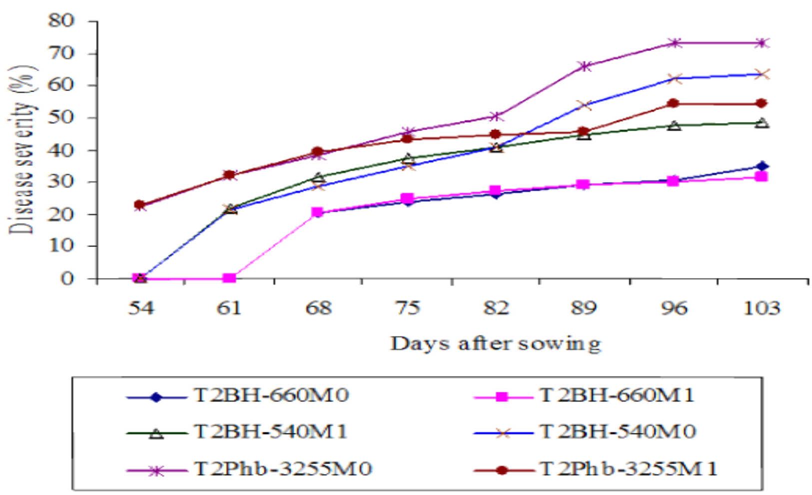

Figure3. Disease progress curves of gray leaf spot under two times tillage and fungicide treatment on three maize hybrid varieties at Bako from 2008 to 2010cropping season. T2 = 2x tillageM0 = mancozeb 80% WP unsprayed and M1 = mancozeb 80% WP sprayed, BH-660= resistant, BH-540 = moderately resistant and PHB-3253= susceptible maize varieties

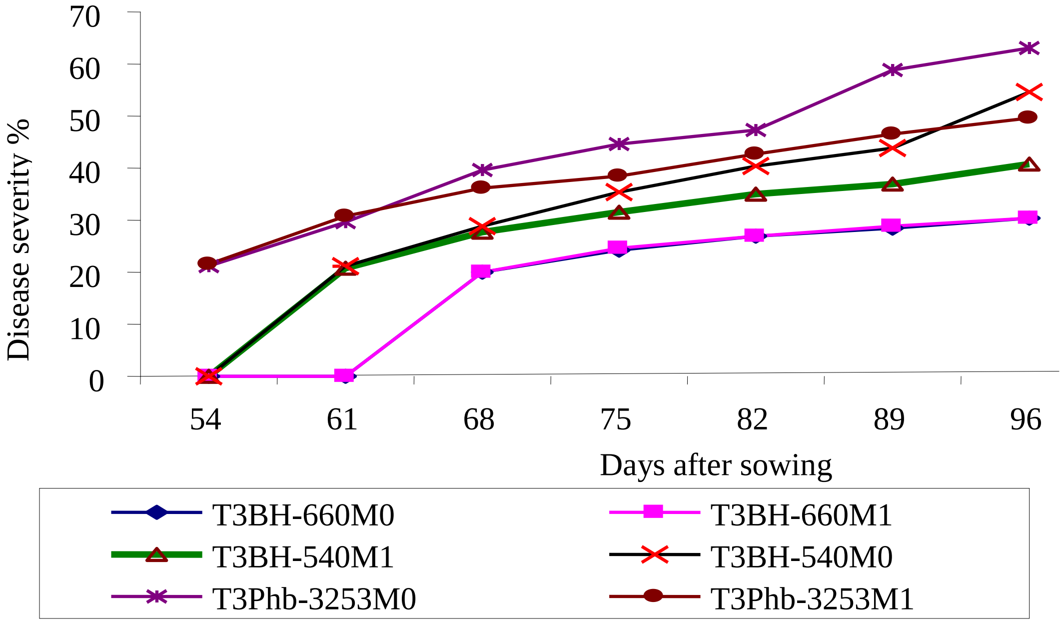

Figure 4. Disease progress curves of gray leaf spot under three times tillage and fungicide treatment on three maize hybrid varieties at Bako from 2008 to 2010cropping season. T3 = 3x tillage, M0 = mancozeb 80% WP unsprayed and M1 = mancozeb 80% WP sprayed, BH-660= **resistant, BH-540 = moderately resistant and PHB-3253= susceptible maize varieties.**

Disease severity

The analysis of variance of GLS severity showed significant ($p < 0.05$) difference among tillage x variety x fungicide application (Table 1). The highest (84.6%) GLS severity was recorded in no tillage x PHB-3253 variety x fungicide unsprayed treatment combinations, which was not significantly different from 1x tillage x PHB-3253 x fungicide unsprayed treatment combinations while the lowest (33.4 %) GLS severity was recorded in 2x tillage x BH-660 x fungicide sprayed treatment combination, which was not significantly different from conventional tillage x BH-660 x fungicide sprayed or unsprayed treatment combinations and 2x tillage x fungicide unsprayed treatment combinations (Table 1). Thus, no-tillage x BH-660 x fungicide unsprayed treatment combinations, 2x tillage x BH-540 x fungicide sprayed treatment combinations and conventional tillage x PHB-3253 x fungicide sprayed treatment combinations could reduce GLS disease severity in BH-660, BH-540 and PHB-3253, respectively (Table 1). According to Dowswell *et al.* (2009) integrated use of fungicide and resistant variety reduced the severity of GLS by 78%.

Area under disease progress curve

AUDPC showed significant ($P < 0.05$) difference in tillage x variety x fungicide treatment combinations. The highest AUDPC (202.9 %-day) were recorded in no-tillage practice x PHB-3253 x fungicide unsprayed treatment combinations, while the lowest AUDPC (111 %-day) were recorded in 2x tillage practice x BH-660 x fungicide sprayed treatment combinations. The treatment with the lower AUDPC is, however was non significantly different from no-tillage x BH-660 x fungicide sprayed and unsprayed treatment combinations, 2x tillage x BH-660 x fungicide unsprayed and conventional tillage x BH-660 variety x fungicide sprayed and unsprayed treatment combinations. Similarly, non-significant ($P < 0.05$) difference were observed in conventional tillage x BH-540 x fungicide sprayed and 2x tillage x BH-540 x fungicide sprayed and 2x tillage x PHB-3253 x fungicide spray and conventional tillage x PHB-3253 x fungicide sprayed treatment combinations (Table 1). Thus, no-tillage x BH-660 x fungicide unsprayed, 2x tillage x PHB-3253 variety x fungicide sprayed or conventional tillage x PHB-3253 variety x fungicide unsprayed treatment combinations and 2x tillage x BH-540 x fungicide sprayed treatment combinations reduced AUDPC of GLS in BH-660, PHB-3253 and BH-540 varieties, respectively (Table 1).

Yield components and grain yield

Ear length and ear diameter

The interaction effects of tillage x variety x fungicide application showed significant ($P < 0.05$) difference in ear length and ear diameter (Table 2). The thickest (16.60 cm) ear diameter was observed in conventional tillage x BH-540 x fungicide sprayed treatment combinations, which was not significantly different from conventional tillage x PHB-3253 x fungicide sprayed and unsprayed treatment combination, while the thinnest (14.63 cm) was recorded in 2x tillage x BH-660 fungicide sprayed treatment combination. No significant difference was observed among different levels of tillage practices x BH-660 x fungicide sprayed and unsprayed treatment combinations (Table 2). This finding agree with Dange 2001 *et al.* finding that ear length and diameter of maize could be reduced 91 – 98% by GLS if conditions are suitable for disease development.

Table 1. The effects of tillage x variety x fungicide application on incidence, severity and AUDPC of maize gray leaf spot at Bako, Ethiopia, during 2008 to2010 cropping seasons

Tillage	Variety	Fungicide	Severity (%)	AUDPC(%-day)
No tillage	V1	M0	42.6 GHIJK	125.67 IJ
No tillage	V1	M1	35.4 JK	118.97 IJ
No tillage	V2	M0	60.6 CDE	161.40 BCDEFG
No tillage	V2	M1	46.6 FGHIJK	139.17 GHI
No tillage	V3	M0	84.6 A	202.90 A
No tillage	V3	M1	55.4 DEFG	159.63 BCDEFG
1 x tillage	V1	M0	40.6 HIJK	121.43 IJ
1 x tillage	V1	M1	36.6 IJK	116.10 IJ
1 x tillage	V2	M0	66.0 CD	175.43 BCDE
1 x tillage	V2	M1	54.0 DEFGH	155.90 DEFGH
1 x tillage	V3	M0	80.6 AB	181.07 ABC
1 x tillage	V3	M1	69.4 BC	176.63 BCDE
2 x tillage	V1	M0	37.4 IJK	113.53 J
2 x tillage	V1	M1	33.4 K	111.60 J
2 x tillage	V2	M0	60.6 CDE	158.57 BCDEFG
2 x tillage	V2	M1	48.6 EFGHIJ	154.87 EFGH
2 x tillage	V3	M0	73.4 ABC	181.67 AB
2 x tillage	V3	M1	50.0 EFGHI	150.53 FGH
3 x tillage	V1	M0	37.4 IJK	114.07 J
3 x tillage	V1	M1	34.6 K	112.13 J
3 x tillage	V2	M0	60.0 CDEF	158.17 BCDEFG
3 x tillage	V2	M1	44.0 GHIJK	133.80 HIJ
3 x tillage	V3	M0	73.4 ABC	178.90 BCD
3 x tillage	V3	M1	62.0 CDE	167.27 BCDEF
LSD (5%)			23.35	33.33

Alpha= 0.05. Means with the same letter are not significantly different from each other. V1=BH-660, V2= BH-540, V3= PHB-3253, M1 = Sprayed with fungicide, M0 = Unsprayed with fungicide and AUDPC= Area under disease pressure curve.

Table 2. The effects of tillage x variety x fungicide application on ear length and ear diameter of hybrid maize (BH-660, BH-540 and PHB-3253) at Bako from 2008 to2010 cropping seasons

Tillage	Variety	Fungicide	Ear length (cm)	Ear diameter (cm)	S. count (n)
No tillage	V1	M0	16.27 BCDEFGHI	14.77 GH	98.3
No tillage	V2	M0	14.20 IJ	14.63 H	100.69
No tillage	V3	M0	14.97 GHIJ	15.23 CDEFGH	99.48
No tillage	V1	M1	19.40 A	14.87 FGH	99.24
No tillage	V2	M1	13.93 J	15.27 CDEFGH	98.99
No tillage	V3	M1	15.13 FGHIJ	15.30 CDEFGH	98.72
1x tillage	V1	M0	18.33 ABCD	14.93 EFGH	98.79
1x tillage	V2	M0	16.13 CDEFGHIJ	15.63 BCDE	99.34
1x tillage	V3	M1	14.23 IJ	15.40 CDEFG	99.22
1x tillage	V1	M1	17.23 ABCDEF	15.17 DEFGH	98.95
1x tillage	V2	M1	16.03 EFGHIJ	15.73 BCD	98.14
1x tillage	V3	M0	14.30 IJ	15.57 CDEF	100.21
2x tillage	V1	M0	17.20 ABCDEFG	14.93 EFGH	100.27
2x tillage	V2	M0	15.20 FGHIJ	15.17 DEFGH	100
2x tillage	V3	M0	17.23 ABCDEF	14.97 EFGH	101.14
2x tillage	V1	M1	15.23 FGHIJ	15.83 BCD	99.44
2x tillage	V2	M1	14.80 HIJ	15.20 DEFGH	99.56
2x tillage	V3	M1	18.37 ABC	15.37 CDEFG	97.14
3x tillage	V1	M0	18.40 AB	15.33 CDEFGH	99.68
3x tillage	V2	M0	18.03 ABCDE	15.73 BCD	100.98
3x tillage	V3	M0	16.10 DEFGHIJ	15.93 ABC	101.45
3x tillage	V1	M1	16.70 BCDEFGH	14.90 FGH	99.44
3x tillage	V2	M1	14.90 HIJ	16.60 A	99.11
3x tillage	V3	M1	14.97 GHIJ	16.33 AB	98.89
LSD (5%)			2.234	0.7313	Ns

Alpha= 0.05, means with the same letter and without letter are not significantly different from each other. V1=BH-660, V2= BH-540, V3= PHB-3253, M1 = Sprayed with fungicide, M0 = Unsprayed with fungicide, LSD = Least significant difference, Ns = Non significant difference and x = time

Grain yield

The interaction effects of tillage x variety x fungicide application showed significant ($P < 0.05$) difference in mean grain yield among different treatment combinations (Table 3). In BH-660 the highest mean grain yield (9328 kg/ha) was obtained in conventional tillage x BH-660 variety x fungicide sprayed treatment combinations. It was not significantly different from all tillage x variety x fungicide sprayed or unsprayed treatment combination (Table 3). In BH-540 variety the highest mean grain yield (9161 kg/ha) was obtained in conventional tillage x BH-540 x fungicide sprayed treatment combinations. It was not significantly different from no-tillage x BH-540 x fungicide sprayed, 2x tillage x BH-540 x fungicide sprayed, 2x tillage x BH-540 x fungicide unsprayed, and 3 x tillage x BH-540 x fungicide unsprayed treatment combinations. Similarly, in PHB-3253 the highest mean grain yield (8926 kg/ha) was obtained in conventional tillage x PHB-3253 variety x fungicide sprayed treatment combinations, which was not significantly different from 2x tillage x PHB-3253 x fungicide sprayed and 3 x tillage x PHB-3253 x fungicide unsprayed treatment. Thus, use of 1xtillage x BH-660 x fungicide unsprayed, 2x tillage x BH-540 x fungicide sprayed treatment combinations and 2x tillage x PHB-3253 x fungicide sprayed or 3 x tillage PHB-3253 x fungicide unsprayed treatment combinations could reduce yield loss that would have been caused x GLS in BH-660, BH-540 and PHB-3253 varieties, respectively (Table 3).

Yield loss

In all varieties (BH-660, BH-540 and PHB-3253) grain and 1000 KW loss were decreased as the level of tillage increased from no till to conventional tillage. The highest grain yield loss (1.6, 24, and 27%) and 1000 KW loss (1.1, 4.7 and 4.3 %) were recorded in no tillage in BH-660, BH-540 and PHB-3253 varieties, respectively (Table 4). This was because in no tillage the varieties were highly infested with GLS disease that resulted in blighting of the whole leaves in susceptible varieties like PHB-3253 (Table 4).

Table 3. The interaction effects of tillage x variety x fungicide application on yield/ha and thousand-grain weight of maize hybrid variety (BH-660, BH-540 and PHB-3253)

Tillage	Variety	Fungicide	GY kg/ha	TKW (g)
No tillage	V1	M0	8553 BC	328.0 AB
No illage	V2	M0	6613 C	264.0 CDE
No tillage	V3	M0	6527 C	252.0 DE
No tillage	V1	M1	8670 B	325.0 ABC
No tillage	V2	M1	8314 BC	268.4 CD
No tillage	V3	M1	8481 BC	262.7 CDE
1 x tillag	V1	M0	8771 AB	323.4 ABC
1 x tillag	V2	M0	6274 CD	252.7 DE
1 x tillag	V3	M0	6274 CD	263.0 CDE
1 x tillag	V1	M1	8772 AB	320.5.0ABC
1 x tillage	V2	M1	6599 BC	265.2 CDE
1 x tillage	V3	M1	8588 BC	264.2 CDE
2 x tillage	V1	M0	8928 AB	319.7 BC
2 x tillage	V2	M0	7303 BC	294.2 BC
2 x tillage	V3	M0	6552 CD	263.1 CDE
2 x tillage	V1	M1	9112 AB	316.2 BC
2 x tillage	V2	M1	9089 AB	298.3 BC
2 x tillage	V3	M1	8886 B	274.9 CD
3 x tillage	V1	M0	9144 AB	333.5 AB
3 x tillage	V2	M0	7375 BC	299.8 BC
3 x tillage	V3	M0	6904 BC	264.6 CDE
3 x tillage	V1	M1	9328 A	336.5 A
3 x tillage	V2	M1	9161 AB	303.7 BC
3 x tillage	V3	M1	8926 AB	276.4 CD
LSD (5%)			1685	67.18

Alpha= 0.05, means with the same letter are not significantly different from each other. V1=BH-660, V2= BH-540, V3= PHB-3253, M0=Unsprayed with fungicide, M1= Sprayed with fungicide and x= time(s)

Table 4. The effect of tillage x variety x fungicide application on maize grain yield and kernel weight at Bako, Ethiopia, during 2008 to2010 cropping seasons

Tillage practice	Variety	Fungicide	Grain yield (Kg/ha)	Loss (Kg/ha)	Loss (%)	TKW[a](g)	Loss (g)	Loss (%)
No tillage	BH-660	M0	8553.0	137	1.6	316.2	3.5	1.1
		M1	8690.0			319.7		
1x tillage	BH-660	M0	8741.0	31	0.3	320.5	3.0	0.9
		M1	8772.0			323.4		
2x tillage	BH-660	M0	8968.0	144	2	325.0	3.0	0.9
		M1	9112.0			328.0		
3 x tillage	BH-660	M0	9174.0	154	1	333.5	3.0	0.9
		M1	9328.0			336.5		
No tillage	BH-540	M0	6274.0	2025	24	252.7	12.5	4.7
		M1	65899.0			265.2		
1x tillage	BH-540	M0	6613.0	1701	20	264.0	4.4	1.6
		M1	8314.0			268.4		
2x tillage	BH-540	M0	8201.0	919	11	294.2	4.1	1.4
		M1	9120.0			298.3		
3 x tillage	BH-540	M0	8175.0	986	10	299.8	3.9	1.3
		M1	9161.0			303.7		

Tillage practice	Variety	Fungicide	Grain yield	Loss	Loss	TKW[a](g)	Loss	Loss (%)
No tillage	PHB-3255	M0	6274.0	2314.0	27.0	264.6	11.8	4.3
		M1	8588.0			276.4		
1x tillage	PHB-3255	M0	6552.0	1929	22	263.1	11.8	4.3
		M1	8481.0			274.9		
2x tillage	PHB-3255	M0	7527.0	1359	15	252.0	10.7	4.0
		M1	8886.0			262.7		
3 x tillage	PHB-3255	M0	7804.0	1122	13	264.2	2.2	0.8
		M1	8926.0			263.0		
LSD (5%)			1685			67.18		

Alpha = 0.05, M0 = Unsprayed with mancozeb 80%WP fungicide, M1= Sprayed with mancozeb 80% WP fungicide and x = times

Economics analyses for fungicide application

The 2008 to 2010 maize price paid to producers averaged 130 birr/ 100 kg and the average costs of fungicide and spray charges were 100 birr/ha. The break-even yield to cover chemical and spray costs was a gain of 76.92 kg grain/ha per fungicide application. In fungicide sprayed treatment it was sprayed four times to protect the maize crop from blighting by GLS from 2006 to 2008 cropping seasons at Bako. The total costs of fungicide and spray were 400 birr/ha. The break-even yield to cover fungicide and spray costs was a gain of 307.69 kg/ha. But the average grain yield of fungicide sprayed treatments were 8660.6 kg/ha and that of fungicide unsprayed treatments were 7434.9 kg/ha (Table 3). The grain yield difference between fungicide sprayed and unsprayed treatments were 1225.7 kg/ha (Table 3). This indicated that the average grain yield of fungicide sprayed treatment exceeded that of the break-even grain yield. The average grain yield obtained between sprayed and unsprayed treatments of the same type of tillage practice also exceeded the break-even yield (307.69 kg/ha) in all tillage practices (Table 3). The judicious use of fungicide is, therefore, economical in all tillage treatments.

CONCLUSIONS

The interaction effects of variety tillage practice and fungicide application showed significant ($P < 0.05$) difference on disease severity. The lowest severity were recorded in 2x tillage x BH-660 variety x fungicide sprayed treatment combination, conventional tillage x PHB-3253 x fungicide application and conventional tillage x BH-540 x fungicide application reduced disease severity.

The average grain yield obtained between sprayed and unsprayed treatments of the same type of tillage practice exceeded the break-even yield (307.69 kg/ha) in all tillage practices. Minimum or no-tillage practice contributed to more disease and greater grain loss than the rest tillage practices irrespective of the varieties used. Thus, use of 1xtillage x BH-660 x fungicide unsprayed, 2x tillage x BH-540 x fungicide unsprayed and 2x tillage x PHB-3253 x fungicide sprayed or 3 x tillage x PHB-3253 x fungicide unsprayed treatment combinations would reduce gray leaf spot in BH-660, BH-540 and PHB-3253 varieties, respectively.

Acknowledgement

I would like to thank Mr. Tadesse Berhanu and Bako plant protection staff for their technical assistance during field work. The financial and material support from OARI is gratefully acknowledged.

REFERENCES

Anderson, B.M. 1995. Gray leaf spot disease- Why do we need it ? How do we we get it? In: Thirty First Annual Conference of the Hillinois Maize Breedng School. 6-7 Mar. 1953. Univ. of Illinos, Urban-Champagien.

Benti T, Tassew G, Mosisa W, Yigza D, Kebede M and Gezehany B. 1993. Genetic improvement of maize in Ethiopia pp. 13-21. In: Benti T, and Jk Ransom (eds). Proceeding of the First National Workshop of Maize in Ethiopia, 5-7 May 1992. IAR/CIMMIT, Addis Abeba Ethiopia.

CSA (Central Stastical Authority). 2011. Agriculture sample survey report on area and production for major crops for 2010/11. The FDRE Stastical Bulletin 137, vol. 9. Addis Abeba, Ethiopia.

Dagne Wegary, Demissew Kitaw and Girma Demissie. 2004. Assessment of losses in yield components of maize varieties due to grey leaf spot. Pest Management Journal of Ethiopia. 8: 59-69

Dagne Wegary, Fekede A. , Legesse W. and Gemechu K. 2001. Grey leaf spot disease: A potential treat to maize production in Ethiopia. pp. 147-157. *In*: Proceeding of the Ninth Annual Conference of the Crop Science Society of Ethiopia (CSSE), 22-23 June 1999. Sebil Vol. 9.

de Nazareno, N. R. X., Lipps, P. E., and Madden, L. V. 1992. Survival of *Cercospora zeae-maydis* in maize residue in Ohio. Plant Dis. 76: 560-564.

Dowswell CR, Palwal RL and center RP. 2009. Maize in third world. Westview Press, INC. Colorado, USA.

Geyers, H. O., Lake, J. K., and Hohls, T. 1994. Diallel cross analysis of resistance to gray leaf spot in maize. Plant Dis. 78:379-383.

Gomez, K.A. and Gomez, A.A., 1984. Statistical procedure for agricultural research. 2nd edition. A Wiley Interscience Publications, New York. pp 122-123.

Nowell, D.C. 1997. Studies on ear rot and gray leaf spot on maize in Kwazulu-Natal, South Africa. Ph.D. Thesis, Dep. Microbiology and Plant Pathology, University of Natal, Pietermaritzburg, South Africa.

Renfro, B.L. and Ullstrup, A.J. 1996. Comparison of maize disease in temperate and tropical environments. PANS 22: 491-498.

Saner, E. and Finney, R.E. 1977. The effect of Nitrogen fertilization on the experassion of slow-mildewing resistance in Konex wheat. Phytopatol. 67: 1051-1056.

Subrahmanyam, P., D.Mcdonald, F.Walliyer, L.J. Reddy, S.N. Nigam, R.W.Gibbons, R.Ramanatha., A.K. Singh, S.Pande, P.M. Reddy and P.V. Subbarao, 1995, Screening methods and source s of resistance to rust and leaf spot of ground nut. Information bulletin No.47, Patancheru. 502324, Andhara Pradesh, India, ICRISAT 24p.

Vasal, S.K. 2000. Quality maize story. In: Improving Human Nutrition Through Agriculture. The Roll of International Agricultural Research. A workshop hosted x IRRI, Philippines, Organized x International Food Policy Institute. Los Banos. October 5-7, 1999.

Ward .J.M.J, Birch E.B. and Nowell D.C. 1994. Gray leaf spot on maize. Co-ordinated extension. Maize in Natal. Cedera Agricultural Development Institute. Cedara, South Africa.

Ward, J. M. J., Laing, M. D., and Cairns, A. L. P. 1997a. Management practices to reduce grey leaf spot of maize. J. Crop Sc. 37: 1257 - 1262.

Ward, J.M.J., E.B. Birch, and D.C. Nowell. 1999b. Gray leaf spot on maize. Coordineted extention. Maize in Natal. Cedara Agricultural Development Instiyute,Cedara, South Africa.

Ward, J.M.J., E.L. Stromberg, D.C. Nowell, and F.W. Nutter, Jr. 1999. Gray Leaf Spot: A disease of global importance in maize production. Plant Dis. 83:884–895.

Wheeler, J.B. 1969. An introduction to plant disease. John Wiley and sons Ltd., London. 301p.